A GUIDE TO SILVICULTURAL PRACTICE

DISTRICT ONE

Historical

P R O T E C T I O N

FOREST PATHOLOGY

By

James R. Weir, Ph.D.,
District Pathologist.

1913

U. S. DEPARTMENT OF AGRICULTURE

FOREST SERVICE

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PROTECTION

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INTRODUCTION.

The cultural aims of the forester are to produce from year to year, at a certain growth ratio, the highest possible amount of merchantable wood. To bring this about it is necessary to protect the individuals of a forest, or the forest community, from such diseases as will threaten the production of this material. For the purpose of acquainting the field men with the nature of these diseases, their cause, and lastly the methods of control, this bulletin is prepared.

Structure of the Tree

In order to have a clear conception of the way in which fungi are able to break down the vigor of a tree, it is appropriate to discuss the functions of the healthy tree and the structure of the normal wood.

In the coniferous and numerous broad leaf trees there is always a permanent increment taking place at regular intervals throughout the entire surface of the plant. This increment is originated and laid down through various changes of the three original primary tissues. The result of the activities of these tissues is usually referred to as the secondary thickening. This secondary thickening, or annual increment, is brought about by the division of the cells of the cambium which lies between the bark and the wood.

The cambium consists of very thin walled cells which at certain periods of the year are capable of rapid division, and are responsible for the yearly increment. This layer of embryonic tissue completely envelopes the entire woody portion of the tree and produces a new layer of wood every year. In the cross section of the stem these layers appear concentrically arranged and are known as annual rings. The sharp line of demarcation between rings is due to the microscopical structure of the cells composing them. The inner side of every ring consists of wide, thin walled cells and forms the spring wood, the outer of thicker cells and forms the autumn wood. Extending from the bark to the center of the wood cylinder are a series of modified cell elements

forming the medullary rays. These consist of parenchyma and afford a means by which food materials are conveyed into the wood. The cross section of a stem presents in the variable form and thickness of its annual rings, therefore, a history of its growth and nutrition. Since these rings correspond to annual periods, they may be used in determining age.

Mature trees usually exhibit a striking variation in color between the outer peripherical wood and the central part. Technically this is the heart and sap wood. The younger sap wood is more or less watery and of few rings in thickness. It is of great physiological importance since it is in this wood that the water is enabled to travel upward in the tree. The heart wood, dark colored in most trees, forms the main portion of the wood cylinder. It functions solely for the mechanical support of the tree and is otherwise unessential to its welfare. It is dead wood, and for this reason it is acted upon by wood destroying fungi.

The wood of conifers consists of very similar cells. These elongated, pointed cells, known as tracheids, are characterized by having on their radial walls conspicuous bordered pits. The presence of these pits distinguishes the wood of conifers from that of broad leafed trees. Some of the tracheids may be highly specialized and of a parenchymatous nature for particular functions, and may be scattered throughout the thicker walled prosenchymatous tracheids, or

located in the medullary rays. They all, however, have the bordered pits. The successful transfer of water and food substances in case of injury to the trunk may depend on the position on the cell of these pits. Some of the wood tracheids are characterized by spiral thickenings on their inner walls, but are confined to the protoxylem (not of cambial origin) of the stem in most genera. In some cases spiral thickenings may be present in the tracheids of the secondary wood, and are provided with bordered pits. Douglas fir and larch are so characterized. In the former the spirals are present in both spring and summer tracheids, but are only in the summer wood of the Larch. The resin secreting tissues of coniferous wood vary considerably, from single resin tracheids, and resin cells, to the more complex resin canals. The simple resin tracheids are not ordinarily prominent in the higher Coniferae. The resin usually collects in a heavy layer about the periphery of the resin cell cavity. Pathological resin tissues may be formed in various conifers when injured by insects, sapsuckers and various other agents that do not normally produce them. Parasitic fungi and mistletoes may cause an abnormal and localized production of resin producing tissues in many conifers which is of considerable pathological significance.

Normal Functions of the Tree.

The life of a tree is only maintained by an uninterrupted opportunity to exercise various functions.

The tree takes from its environment various raw materials and elaborates them to its use. This results in growth, with the attendant change in form and volume and adjustment to its environment. Lastly, since its length of life is limited, it produces individuals of the same species.

All of these functions, viz: food absorption, respiration, growth, adjustment and propagation, are the result of chemical and physical processes, and are dependent on the influences of forces acting upon the various organs specialized for a particular work. These outer forces, or the environmental conditions, are food, oxygen transfer, water, warmth, light and gravity. Of these the most important is oxygen and warmth. Without the former all life is impossible. Some of the bacteria are the only known forms of life that can exist without oxygen. In like manner for all life functions a certain temperature over -0° is necessary. The optimum temperature for the most of the life functions lies between 25° and 35° C.

The result of the activities of various fungi by attacking the vital organs of the tree is to reduce its capacity to exercise the necessary functions for self maintenance.

Nature and Cause of Disease.

The disturbances of the normal functions of a tree may be induced by a great variety of agencies, the resulting diseased conditions being manifest by more or less characteristic symptoms or signs, such as fruiting structures, resin flow, swellings, punk knots, cankers, shrinkage of branches, wilting and yellowing of leaves, etc. The observation and accurate description of symptoms is often difficult. Symptoms of disease may be of a general nature. This is due to the less organized nature of plants as compared to animals, or perceptions may differentiate imperfect symptoms when due to a variety of causes. Yellow and falling leaves, a very common indication of disease, may be caused by drought, temperature extremes, too much or too little light, excess of water at the roots, fungi, insects, poisonous gas, etc. Great caution is necessary, especially when the untrained eye has taken no notice of the collateral circumstances of the case. No one of the proximal causes may be solely responsible.

The reactions exhibited by some forest trees as expressed in form and structure under different conditions of growth, such as slope, crowding, or the peculiarities sometimes induced by sudden exposure on sales areas are not to be interpreted as indicative of unhealthy or diseased conditions. The morphological and physiological changes are more to be considered as normal and purely within the ability of the tree to respond to varying amounts of light, heat, and nutritive materials. Since an ideal relation between the tree and ex-

ternal factors is seldom, if ever, realized, a varying response on the part of the tree's organization is to be expected. Although the first operative forces receive a greater response in the early life of the tree and more or less determine its later form and structure, the fact that such early response may be diverted into other channels is only an index of the tree's recuperative ability, the work that every plant organization attempts to perform, viz: self-maintenance and perpetuation of its kind. It is clear that if a tree is to realize these two great functions in their fullness, it must possess a certain amount of functional flexibility. A tree may exhibit a loss of vigor due to certain indeterminable causes. The casual factors inducing the loss in vigor must necessarily retain the dominating influence until another or stronger impetus lays hold of the tree's organization. The intermediate condition may then serve as merely a tiding over of adverse influences. Strictly pathological conditions may not appear since the life functions were not reduced to the lowest proportions. The chief component of a lower story forest often illustrates every stage of suppression and recovery indicated in the above statement and still appears as the climax forest in a state of vigor and health not shown by any other species of the stand. Only when the normal functions of the tree under the influence of outside factors are so very greatly changed as to produce a positive injury to the living cell, can we speak of a strictly pathological condition. The possibility of a forest tree maintaining a more or less stable

condition between the maximum and minimum of these factors or even to find its optimum depends upon its ability to cope with new environments. These may suddenly arise even in a permanent stand by flustuations of climate, thinning, etc. Previous or early conditions of existence would also be of some significance. This may be illustrated as follows: If trees grown under south slope conditions were transplanted to north or northeast conditions, or if seedlings of the same species were grown under exactly the same cultural conditions, but at different temperatures, they would exhibit an entirely different response to the influences of frost and other weather conditions. The determination of the factors under which forest tree species in particular regions will attain their optimum development will often explain away an apparent pathological condition. To determine the danger line in the gradation between health and disease is often very difficult. Any factor that influences the amount and quality of the food supply of a forest stand determines very largely its general state of health. Since the attendant phenomenon of reduced vigor in such a case may be due to local conditions and may not have extended over so long a period as to induce so-called constitutional tendencies to disease, other causes must explain the general disability of certain members of a forest stand to maintain a high state of health. Probably no factor so over-rules all others in forest growth as the continual strife of trees with one another for space and light. For the more intolerant species this has a far greater significance from a standpoint of disease than for the shade-loving or tolerant species.

Claims of causation of disease and the factors concerned will be grouped differently to suit different cases. Bearing this in mind, the determining causes of disease, which are very numerous and often obscure, may be outlined as follows:

I. Diseases caused by external agencies:

A. Inanimate (non-living) agents of disease.

1. Diseases induced by unfavorable soil conditions.

a. Chemical conditions of the soil.

b. Physical character of the soil.

2. Diseases induced by natural atmospheric phenomena.

a. Violent rain, heavy dew, hail, sleet, show, cold, frost, heat, light, sun, wind, drought, floods and lightning.

3. Diseases by non-atmospheric natural phenomena.

a. Avalanches, shifting sand, erosion, forest fires (started by lightning) and natural mechanical injuries.

4. Diseases induced by chemical injuries.

a. Illuminating gas, sewer gas, factory gases, smelter fumes, dust from cement works, acids, poisons and dyestuffs which pollute streams.

B. Animate (living) agents of disease.

1. Animal agents of disease (resulting in mechanical injury.)

a. Natural wounds, nematode worms, mites, insects, rodents, grazing animals, and birds.

b. Artificial wounds resulting from man's activity. Fires, lumbering, guy wires and climbers, electrical injuries from leaking wires, blazing, pruning and flooding of timbered areas.

2. Vegetal agents of disease.

a. Smothering by lichens and non-parasitic fungi.

b. Phanerogamic parasites.
Mistletoe and various plants parasitic on roots.

c. Cryptogamic parasites.
Slime molds, bacteria, green algae and fungi

II. Diseases caused by internal agencies- the so called functional diseases, due to abnormal activities, mostly enzymatic, within the plant itself.

The Nature and Development of Fungi.

The diseases of forest trees in most cases are due to fungi. A brief resume of the nature and development of these plants is necessary in order to appreciate their relation to disease.

The fungi form a large group of the spore or cell plants, in contrast to the seed or vascular plants. The latter originate from an embryo in the seed with the formation of cotyledons, the former develop from the undifferentiated contents of the so called spore. The spore germinates without the formation of cotyledons and develops at once by a rapid multiplication of like cells into a new plant. The most marked distinction between the fungi and seed plants lies in the development of their respective vegetative systems. The vegetative system of the seed plants (Phanerogams) is composed of the roots, stems and leaves, while in the spore plants (Cryptogams) the functions of these three highly differentiated organs are usually carried out by a single undifferentiated structure, the thallus (mycelium of fungi).

If one of our common wood destroying fungi is examined it will be found that the vegetative part of the fungus which ramifies through the wood cells of the host consists of filamenteous elements (the hyphae.) These hyphae are characteristic of all fungi and produce the fruiting body of the fungus. While the hyphae of all fungi have more or less the same character, the fruiting structure arising from them are character-

ized according to the manner in which the spores are produced by a great variation in form and structure.

A fungus may propogate itself by means of its vegetative system, by various minor or secondary bodies capable of germination and by spores. The most common method of propagation is by means of spores. Although the fungi consist of cells as do other plants, these cells are entirely devoid of chlorophyll. For this reason they are dependent upon organic substances for their nourishment, which explains their importance in plant disease. Under the influence of the sun the carbonic acid of the air taken up by the cells of green plants is broken up into carbondioxide and oxygen. Oxygen is given off and the carbon dioxide is combined to form starch and sugar. This method of nourishment is in great contrast to that of the fungi which must have food already prepared for them. They obtain this food from various substances. If it is derived from decaying or dead organic matter, the fungus is said to be a saprophyte. If the fungus mycelia invades the tissues of livin organisms (the host) it is said to be a parasite. The cellular tissues of the host are acted upon in various ways and disease results.

The spores of fungi are, as a rule, of very simple structure. They are of mycroscopical size, usually round to oblong and may consist of one or more cells. They are produced on or in various kinds of frustifications. Upon the form and structure of these fructifications the classification of the fungi is based.

Systematically the fungi are divided into three major groups: Phycomycetes (Algal-like, or lower fungi), Ascomycetes (asc-fungi), and Basidiomycetes (basidia-fungi). The last two groups constitute the higher fungi.

The Phycomycetes are characterized by a continuous mycelium without cross walls. To this group belong some of the most important "damping-off" fungi, which cause great destruction of seedlings in forest tree nurseries.

The Ascomycetes are characterized by the production of from 2, usually 8 spores in a sack-like structure, known as the ascus (plural asci). At maturity the spores are forceably expelled. The asci may originate singly or in groups from the parent mycelium, or may be housed in definite and characteristic fruiting bodies. These fruiting bodies are either open (apothecia) or closed (perithecia). After the asci are formed from spicial ascogenous hyphae sterile filaments appear among them, the whole forming what is usually known as the hymenium. In some Ascomycetes a sexual process has been observed, but in many cases the asci originate without fertilization. In addition to the spores in the ascus many Ascomycetes produce various kinds of secondary spores (conidia). These are either cut off from free standing conidiophores or originate in special structures (pycnidia). This ability to produce several spore forms is sometimes called pleomorphism. Many of these spore forms have not been connected with the ascus type of spore production and are known as the imperfect fungi (Fungi Imperfecti).

To the Ascometes belong some of the most important parasites of forest trees. The chestnut bark disease, leaf and needle cast, many cankers on conifers, and various types of witches' brooms, are caused by Ascomycetes.

The Basidiomycetes include the large tree fungi and all such forms commonly known as toad stools and mushrooms. The forest tree rusts also belong in this group, which still retain, to a certain extent, a sexual mode of reproduction. In the majority of Basidiomycetes sexual reproduction has entirely disappeared. The spores of the Basidiomycetes are born usually in groups of four on special structures known as the basidium, which form a layer (hymenium) on the under side of the fruiting body. All the fungi which attack the heart wood of living trees belong in this group, and are classified according to form and arrangement of this fruiting layer. Some of the most important genera are Polyporus, Fomes, Trametes, Hyduum, Daedalea, Pholiota, Armillaria, etc.

Methods of Infection by Fungi.

The uninjured bark upon the living tree is a natural protection against the entrance of most of the wood destroying fungi. Any opening through the bark caused by natural or artificial agencies exposes the sapwood or heartwood. If the exposed wood is not immediately protected, as is the case in most conifers, the wood dries out and checks. Spores of wood destroying fungi find lodgment on the exposed surface, where they germinate and infect the tree. This is the method by which all the wood destroying fungi, which do not normally attack the roots, enters the tree. A few wood destroying fungi are parasitic. They are usually confined to the roots and may infect the tree without the intervention of wounds. These fungi may propagate themselves vegetatively by extending the mycelium from tree to tree through the forest litter. The true parasitic fungi, such as the rusts and many of the Ascomycetes, may educe infection on the younger parts of trees by direct penetration of the young bark, terminal buds, etc.

After a wood destroying fungus becomes established in the heart wood of its host the mycelium spreads up and down the trunk destroying the wood. After the mycelium reaches a certain stage of development or maturity, a process hastened by the exhaustion of the food materials in the substratum, fruiting bodies may be developed at various points on the outside of the tree. These fruiting bodies ("punks", "conks"), may be the first noticeable indication of the presence of decay. Their number and location on the trunk is usually a good indi-

cation of the amount of rot.

The Decay of Wood by Fungi.

Wood decay is always caused by fungi, aided by bacteria in later stages of decay. The action of the fungus on wood is a pure nutrient relationship. The demands of the different fungi for particular food substances may produce various changes in the wood, resulting in characteristic decays. Aside from certain natural fermentation processes set up by the respiration of the mycelium, there is usually a complete breaking down of the cell wall elements through the influence of special enzymes excreted by the mycelia. These enzymes have the power to break down carbohydrates, fats and albuminous compounds without themselves being changed in the process. Illustrative of the action of these enzymes is the hydrolization of starch into several intermediate substances. The splitting up of reserve cellulose into various products is another example. These processes may not be rapid in the wood. A fungus can only utilize those substances actually taken up by its mycelia, the amount depending upon the extent and demands upon its vegetative growth, as in the production of sporophores, etc. The breaking up of albuminous compounds may be brought about by different enzymes, working specifically at different stages of the disorganization. These intermediate stages, first albumose, then peptone, and finally as the complete result of the disorganized albumens, the aminoacids, with the exception of the latter, still have much in common with the

original compound. The wood, however, is greatly affected. The fact that the mycelia of our common wood destroying fungi produce these enzymes (ferments), enables them to bore through the cuticularized cellulose walls disorganizing the cell content, and the wood structure in general. This is the work of most of the tree fungi with which we have to deal. The manifold variation in which the various species exhibit in breaking down the woody tissues show that there must be special or particular adaptations between certain fungi and the wood inhabited by them. Also in the manner in which the disintegration is brought about. Some species dissolve from the woody cell wall coniferine and cellulose only, leaving the lignified portion of the wall. This action causes the familiar brown or carbonizing rots. The enzymes of some fungi act principally on the lignin, leaving the cellulose. This action causes the so called delignified or white rots. The fact that the entire groups of fungi may produce the same changes in the wood explains the seemingly constant character that the wood of different trees exhibit in decay. The variation in the structure of wood may influence the type of decay, but ordinarily the same characteristic rot is produced by any particular fungus, regardless of the species of tree on which it grows. This is true at least for some of our common wood destroying fungi. But it is unsafe to refer a rot in every case to a particular fungus when the sporophore is not found.

Specific Description of Diseases.

Before presenting the practical aspects and relation of forest pathology to forest regulation, it is first necessary to become acquainted with a few of the most important factors causing disease in trees. The diseases to which our forest trees are subjected may be discussed, as previously indicated, in accordance as they are induced by various inanimate and animate agents, such as atmospheric influences, soil, Cryptogamic and Phanerogamic plants, etc.

1. Injuries primarily resulting from causes other than Cryptogamic plants.

Results of Injury by Fire: We have a number of northwestern conifers which show great sensitiveness to high temperatures. The susceptibility to fire injury by these trees aside from any particularity of root system, foliage, etc., hinges in a large measure on the thinness of the bark as compared to their associates. Aside from the immediate destruction of immature and mature growth, the action of ground or surface fires is to produce a disposition of the slightly injured trees to all manner of disease of roots, trunk, and foliage. The more indirect consequences of fire would be the loss in the food producing capacity of the soil by washing, leaching, action of sun, wind, and growth of weeds and other noxious plants. From a pathological standpoint the destruction of the humus has a greater significance. The humus soil always is in an active state of decay, aided by its ability to retain moisture and by the immense number of cryptogamic organisms contained in it, many of which, as mycorr-

hiza, are intimately associated with the roots of trees in the absorption of food and are, in some cases, apparently necessary for the growth of some of our commercially valuable species. The fact that the forest mould may contain funguus forms injurious to forest trees is entirely offset by the invigorating effects of the humus on the growth of the trees, hence reducing the possible disposition to disease of the aerial parts. Owing to the fact that this fertile bed is usually attractive on some sites to a second story growth of tolerant species, the site is unfavorable for grasses, herbaceous plants, shrubs, etc., likely to be the alternate hosts of many heteroecious leaf and twig diseases.

Whether or not the natural succession of tolerant species in a type and their subsequent stabilization are to be considered a menace in every instance will depend on the disease attacking them. In most cases, in our own region, the diseases of tolerant species are not of economic importance on the intolerant species. On the other hand, the silvical significance of these tolerant species may sometimes be very great. The appearance on burned areas of forest tree species other than those originally found in it is not always a menace by reason of any disease they might carry, and the transition species may not prove susceptible to the diseases of the primary stand. This is not always true in the case of other plants.

After a fire sufficiently intense as to destroy every vestige of humus and litter the succession of smaller plant life on some sites almost invariably establishes one or more plants that serve for the alternating hosts of some virulent

needle or twig disease not found on the site before the fire. The transition by fire of species into a new environment will then greatly intensify pathological conditions. It is likewise evident that the restoration of the balance between species will have some bearing on the history of diseases in the surrounding unburned areas or, as we have already indicated, on the health of the climax species of the area burned.

Probably the most immediate result of fire injury from the standpoint of what we shall here call disease is the appearance in the wood of fire injured trees of chromogenic fungi, in particular, the common sap stain fungi, Ceratostomella species. These fungi color the dead wood of the wound, often penetrating well into the more vital portions of the sap. In the case of western white pine, which invariably succumbs within a few years after being injured by fire, the blue stain fungi rapidly spreads throughout the entire sapwood and no amount of expedient work on the part of the logger can save the sap from staining. It has been determined that the mycelium of the bluing fungus is only prevented from entering the living sapwood by the high water content of the cells as determining the presence of the necessary amount of oxygen demanded by the fungus.

The relation of basal fire scars to fungus attack is shown by the fact that out of 450 fire-scarred trees of all species and ages examined on sale areas in District One, 85 per cent were butt-rotted. The rot may have been present in some cases before the formation of the scar, but its infrequent occurrence in unscarred trees on the same areas implies the im-

portance of fire scars in relation to decay. On slightly scorched trees hidden scars are formed, viz., the slightly checked bark remains intact over the injured portion and may not fall away for a considerable period of time. These scars are a means of entrance for fungi. The cavity which usually forms between the bark and wood is a natural culture chamber and infection readily occurs. In general trees with resinous wood show a greater number of large fire scars, but it is doubtful if the presence of resin in the wood has any greater significance than that it promotes the inflammability of the exposed wood in old fire scars, making them larger with every recurring fire.

"Wound rot", another injury reducing the quality of the wood of living forest trees is the discoloration of the exposed tissues on coming in contact with the air, and the depredations of wood-boring insects. This "wound-rot", which may take place without the cooperation of fungoid parasites, is often accredited to the bluing fungus or other fungi. As a matter of fact this early reaction to exposure is not a decay but a coloring up of the exposed wood through oxidation of the cell substances and the action of enzymes. The real decomposition of the woody cell is only brought about by fungi and the so-called "wound rot" is only the forerunner of the more serious condition resulting from the chemical action of the numerous fungi which enter at the various types of wounds to be later described.

Influence of Soil on Diseases. It is frequently noted in the transition zones of different forest tree types which

require different site conditions that some trees which have succeeded in establishing themselves in soggy, stony or poorly drained soils may show a stag-headed condition. In some cases the tap root is found decayed; in the absence of fungi and insects, there is little room for doubt but that the sickly and reduced vigor of the tree is directly referably to the tenaciously rocky, compact or soured condition of the soil. It is not generally entertained that an actual decomposition of wood results from a purely chemical action of the organic or inorganic acids of the soil, although this may be possible under very specific conditions of stagnation and insufficient aeration. The fermentative action of bacteria and moulds, together with the presence of higher fungi, made more active by the constant conditions of moisture, no doubt are largely responsible for this type of root rot.

In wet soils underlaid by an impervious stratum of clay or other tenacious formations some forest trees fall under a very moderate wind when left unprotected, The "hard pan" does not admit of the penetration of the tap root to any depth and also retains the moisture comparatively near the surface. The horizontal roots of white pine and larch have been noted to bow up toward the surface or even above it under the influence of such conditions after the manner of certain swamp-growing trees, and presumably for the same purpose. Shallow rooting species, such as spruce, growing on the same site do not ordinarily show a root rot and for this reason are more wind firm.

Atmospheric Influences as a Cause of Disease.

Frost injury: Frost shakes or checks are often very frequent in smooth-barked species, especially in regions of fluctuating and sudden abnormal temperatures. In the older age classes, such checks reduce the quality of the wood for the various technical purposes and open the trees to numerous wood-destroying fungi. The vitality of a tree may be in no wise impaired and the wound in many cases may be effectually healed, but is liable to re-open with the re-occurrence of severe frosts. Such inevitable factors can scarcely be controlled but the avoidance of "frost holes" or "frost belts" is to be recommended in silvical projects. From the standpoint of fungous enemies every frost checked tree should be marked for cutting in all timber sales.

Frost injury to seedlings in cut-over areas is by no means uncommon. It is difficult always to determine how this injury is initiated, but it seems probable that since it more frequently occurs in seedlings standing near reflecting surfaces, fallen bare trunks or polished rock surfaces, the reflected warmth induces premature physiological activities in the spring. On exposed sites and in "frost pockets" winter-killing of seedlings and the younger parts of more mature forest growth frequently occurs. Premature or rapid transpiration due to "chinook winds" at a time when the roots are frozen is probably the cause in some cases. The so-called "red-belt disease" in certain sections of Montana is an example of this type of injury. The wilting down of the terminal twigs is often the means of various semi-

parasitic leaf and twig fungi gaining entrance into the weakened but still living parts of the branch.

Heat Injury: It has already been indicated that thin-barked species are under certain conditions sensitive to high temperatures. This is frequently forcibly demonstrated by their reaction during long exposure and the direct rays of the sun. Providing the soil contains sufficient moisture by which the equilibrium between transpiration and the necessary water content of the living cell may be maintained, many of our conifers, though not naturally occurring on a dry site, can withstand a great deal of atmospheric warmth after they once become established. When such is not the case, numerous instances have come to hand where trees have exhibited such a distinct falling off in increment and showed such peculiar colorations of the foliage that it necessitates proper precautions being taken in planting some species to prevent any undue exposure of soil and site.

For example, the fairly deep root system of white pine enables older age classes to withstand a considerable amount of drought and exposure, whereas young seedlings either in the nursery or in the open forest, or especially in clear cuttings or burnings frequently succumb to the sun's heat. An examination of the conditions surrounding both aerial and subterranean portions of the seedlings during such periods, leaves no room for doubt but that the heat of the sun is the primary cause of death. In regard to mitigating the effects of exposure to the sun on natural reproduction, on all low

level tracts where conditions are more apt to fluctuate and where the greatest injury appears proper protection should be and usually is provided by the rapid appearance of various kinds of plants. The annual and diurnal fluctuations of heat is greater in such situations and the relative humidity and the abundant precipitation of uneven or mountainous regions is not near so pronounced.

Injury to Isolated Trees: Aside from injury resulting from natural exposure to the sun, damage often results to vigorously growing trees on suddenly being exposedat the edges of sale areas. The same may occur in the case of isolated seed trees, or blocks of trees left for the purpose of reseeding. The injury resulting from such exposure is in most cases due to the premature starting of the physiological functions in the spring before the ground has become sufficiently thawed to allow the absorption of water by the roots.

A form of heat injury frequently noted where trees are exposed to edges of cutting areas, seed blocks, forest roads, etc., is the actual scorching of the bark on the younger parts of older trees. Those of pole size are still more liable to this kind of injury. The bark dries out, curls up, and wounds are often formed of no mean proportions. This type of wound seldom protects itself by a flow of resin. Such trees, however, should be allowed to remain, if not diseased, as their removal would only expose others to injury.

Other Injuries. The density of the crown of individual trees is not always sufficient to uphold any great amount of snow,still the closeness with which young trees sometimes

grow may collectively support a sufficient amount of snow to cause considerable breakage. The trees likewise become bent over and remain so long under the influence of the strain that they lose the ability to resume their former position, and if they do not eventually die they become a menace to their neighbors. The openings thus made in the canopy of the stand are always a means of introducing injurious factors. Snow slides are by no means infrequent in the mountains of the Northwest and the damage resulting is in some cases very great, not only in the immediate destruction of valuable timber, but secondarily other destructive agents, as fungi and insects, are introduced. After a slide once occurs, it is extremely difficult for nature to reforest the area, as new slides usually follow the path of the old one. Since the nature and general density of foliage determines in a large measure the retention of snow in the crown of forest trees, mixed forests are to be recommended on all sites liable to snow injury. A certain percentage of Larch in the stand, owing to the deciduous nature of its foliage, is desirable on such sites. The various root systems of the different species in mixture is also a factor to be considered in combating snow slides, the effects of storms, strong winds, etc. As a protection to the more valuable stands on lower levels all precipitous slopes above wherever possible should be maintained in closed forest.

<u>Lightning</u>. Lightning is a common source of injury to forest trees. Some species prove more sensitive and recover with greater difficulty from this form of injury than others. If the trees are not broken up and killed directly, then long, usually

spiral, wounds leave the cambium and sapwood unprotected. By striking old, dry snags lightning is very often the direct cause of forest fires. The influence of lightning on the growth of trees actually struck is usually expressed by the modification of the cells of the annual ring of the season so that the continuity of the normal structure of the wood is broken, making a possible defect in the wood when used to sustain heavy loads. There is no practical means at hand to mitigate the dangers from lightning to forest growth, still known "lighting belts" might be avoided or species exploited that experience shows to be fairly free from this form of injury.

2. Diseases caused by Cryptogamic Plants, Fungi.

Most of our valuable timber trees are subject to the attacks of a number of very destructive fungi. Those attacking the trunk are directly dependent upon various types of wounds for entrance into the tree. Those working in the roots and basal portion of the trunk may or may not be dependent upon wounds. The virulence of those attacking the twigs and needles may be greatly augmented by many of the unfavorable conditions indicated under atmospheric influences, still they are in most cases true parasites and may work great injury to the trees providing sufficient moisture is present. The most important fungous diseases of our western conifers will be briefly discussed according to their position on the host or the parts most affected.

Fig. 1. Fomes pini

on Larix occidentalis

showing relation to rot.

Fungi of the Trunk and Branches.

Wood Rotting Fungi: Fomes pini* (ringscale fungus). (fig.1).

The sporophores of this fungus are either hoof or shell shaped, perennial, hard, woody, with a dark brown upper surface, rough, hairy when young, with concentric raised zones. The context is brown. The pores are usually large and round, sometimes daedaloid. The pore layer is stratified, indistinctly so in young or thin specimens. The underside of the sporophore is brown, usually lighter in color than the context.

The loss of merchantable material occasioned by this fungus is very great. It is the chief enemy of the western white pine, but attacks practically all conifers. Arranging the hosts of this fungus according to species most infected it would be in most regions of Idaho as follows: White pine, larch, spruce, Douglas fir, lodgepole pine, cedar, hemlock, and grand fir. Except under very special conditions, as in the case of root grafting, infection always takes place by means of spores and their ability to germinate, or at least the penetration of the host by the mycelium, has been found to depend upon the freshness of the wound which is principally

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* All species of Polyporaceae with perennial hard, woody, distinctly or indistinctly stratified sporophores are grouped in the genus Fomes.

that of a branch and before it has had time to become thoroughly protected with resin. This explains why it is that the older age classes may be most frequently attacked. The heartwood of the branches is poor in resin and the wounds are left unprotected for a greater length of time, also the branch wounds of older trees are larger. The branch wounds of veterans are particularly susceptible to infection. The fungus may remain dormant in fairly young trees or species rich in resin and later become pronounced with the increasing age of the host, hence only the older age classes seem to be selected. The abundance of resin in the living sapwood of resinous species, also of the outer heartwood prevents the promiscuous appearance of sporophores and are always produced except in the case of the last stages of decay at points of deep wounding, old branch knots, fire scars, etc. For similar reasons the mycelium for long periods confines its activities to particular annular rings giving rise to the familiar "ring rot" or "Ring scale." Sporophores are usually not produced until a luxuriant mycelium has developed, indicating also that the decay is well advanced. These are points to be held in mind by markers. It is not uncommon to find sporophores measuring a foot or more in breadth and showing an age of fifty or more years. At the same time numerous smaller sporophores may be produced from the same mycelium.

Soil and climate have considerable influence on the occurrence of the fungus and amount of damage done, but it occurs in all forest types from that of the yellow pine to the zone of the alpine fir. The prevalence of the fungus also depends on the frequency and nature of the injuries to which stands

in particular regions or sites undergo. It often happens that stands on the more exposed slopes or at the upper limits of the type are badly infected, which is a condition bearing more directly on the breakage of the branches and apical portion of the crown by snow and wind than from any peculiarity of the soil or general environment. The fungus fruits quite abundantly on fallen trees.

Fomes pini causes a heart rot in resinous trees, heart rot or sap rot in trees of little or no resin. In early stages the rot is of a reddish color in split section, with small or large white elliptical patches; big, punky, soft brown in cross section. In typical stages the patches become more numerous and the annual rings separate. It is a delignifying rot converting the wood to cellulose and is conical in both directions from the area of greatest decay. Oftentimes the rot is patchy throughout the trunk, not uniformly attacking the heartwood.

Fomes laricis (chalky quinine fungus) (fig.2).

Sporophores perennial, hoof shaped, frequently cylindrical, snow white when young, with a thin, smooth crust, which later breaks up into a rough brown or gray surface. The flesh is white, soft, friable, and bitter to the taste. Pores small, white, drying yellowish, arranged in layers.

This fungus chiefly confines its activities to yellow pine and larch, but is particularly associated with the latter species in most regions of the Northwest. This latter fact

Fig. 2. Fomes Laricis

Growing from old fire scar

on Larix occidentalis.

tends to promote the spread of the fungus in yellow pine stands wherever this species occurs in mixture with larch. The fungus usually affects its decay in the upper part of the trunk, and, less frequently, at its base. If entrance is effected at the base the rot usually extends throughout the entire merchantable length. Broken branches and lightning scars are found to be among the causes of entrance in the crown, while fire injury is frequently responsible for infection at the base. Trees attacked by this fungus are usually of an advanced age, noted usually in connection with stands growing on well drained gravelly soils. In narrow canyons and on low flat sites having a mixture of yellow pine, larch and Douglas fir, trees of a younger age class are attacked.

Fomes laricis produces a reddish-brown friable heart-rot, breaking up into cubical or rectangular blocks. The rot is similar to that produced by *Polyporus Schweinitzii* and *P. sulphureus*.

Fomes pinicola (Red belt Fomes.)

Sporophores perennial, hard and woody, flat or hoof shaped, upper surface smooth, furrowed gray or black, often with a reddish or yellowish resinous crust; margin rounded, white, yellowish or reddish; context whitish, yellowish or wood colored; pores in distinct layers with circular white to cream colored mouths.

This fungus chiefly attacks the wood of dead trees, but it is also found to be the cause of a heart rot in the base and trunk of living grand fir, larch and hemlock. The fungus produces a uniform carbonizing rot. In early stages the rot

Fig. 3. Echinodontium tinctorium

Indian paint fungus on
Tsuga heterophylla - showing relation
of sporophore to internal decay.

is light brown, breaking up into rectangular blocks of varying size, crumbly and brittle when dry, layers of mycelium are formed in checks between the blocks. The type of decay is the same in both coniferous and broad-leaf species.

Echinodontium tinctorium (Indian paint fungus) (fig. 3).

Sporophore perennial, hoof shaped, dark above with concentric growth zones; context brick red; lower surface covered with hard spines when mature.

The Indian paint fungus is responsible for practically all the decay in western hemlock, grand and alpine fir. It is very rarely found on other species. The fungus causes a uniform stringy brown rot of the heartwood. It enters the tree chiefly through branch knots, frost cracks and various mechanical injuries. The sporophores are developed beneath old dead branches and in large numbers. In the absence of sporophores, infection may be detected by the presence of a rusty red color a half inch or so within the dead branch stubs.

Polyporus sulphureus (sulphur fungus.) (fig. 4.)

Sporophore annual, broad superimposed pilei somewhat stipitate, soft; surface tomentose when young, smooth when old; zonate at times; lemon-yellow to orange, becoming white with age; flesh cheesy-white when fresh, friable when dry; pores small, sulphur yellow.

The sulphur fungus attacks all our important conifers, but principally larch and yellow pine. It produces an uniform heart rot. In early stages the rot is light brown

Fig. 4.   Polyporus sulphureus

on

living Larix occidentalis.

Fig. 5. Pholiota adiposa.
on Abies grandis
growing from a frost crack.

becoming reddish brown, brittle, dry and crumbly with thin felty mycelial masses in the clefts. It is chiefly a butt rot, but infection may occur on other parts of the trunk. The type of decay is the same in both conifers and broad-leaf species.

Pholiota adiposa (Scaly or fatty Pholiota). (fig.5).

Sporophore annual, mushroom type, usually appearing in dense clusters; surface of cap yellow, sticky when moist, covered with rusty brown scales which disappear with age; stem yellowish, scaly at base, with tufted ring; gills yellowish to brown.

The scaly Pholiota attacks a number of conifers, but is chiefly associated with grand fir and hemlock or with trees with little or no resin in the wood. The fungus produces a uniform conical heart rot. The early stage of the rot is detected by a light yellow stain, the wood later becoming stringy, honey yellow in color with brownish streaks and white felty masses running across the grain, finally breaking up into the separate annual rings.

The fungus is usually found fruiting in great masses from old branch knots and frost cracks.

Rust Fungi:

~~Cronartium Comandrae~~ (Pine-Comandra rust.)

This fungus produces fusiform swellings without modification of the wood on the stems of young, hard or yellow pines

and on the branches of mature trees, rupturing in spring with a mass of yellow blisters full of spores, which are pear-shaped. Alternate stage on Comandra, the bastard toad flax. Very destructive to young yellow pine. Young trees 5-10 years old soon succumb to the attacks of this fungus and the mortality of seedlings is often very great in the open forests. The gross appearance of the rust is similar to that of the white pine blister rust and is chiefly distinguished from the following species by the shape and rich orange color of its spores when fresh.

Cronartium stalactiforme (Pine blister-Castilleja rust).

This rust, which has its telial stage on the Indian paint brush, and related plants, forms but a scarcely distinguishable swelling, without modification of the wood, on branches and trunks of lodgepole pine and yellow pine. The yellow blisters containing the spores project through the bark and are very conspicuous when mature. The fungus is not only destructive to reproduction in the forest but also appears in nurseries.

Cronartium Harknessii (Pine gall-Castilleja rust). (fig.6).

Causes conspicuous spherical swellings or galls on the branches and stems of lodgepole and yellow pine. The wood is strongly modified. Before the stem is completely girdled the branches above the gall are often stimulated to form brooms. This fungus is the cause of the "cat face" cankers so common in lodgepole stands and is one of the worst enemies of the lodgepole pine throughout its range. The telial stage of the

Fig. 6. Cronartium Harknessii.

Pine Gall - Castilleja rust,

Galls - on yellow pine;

Alternate stage on Castilleja species.

fungus is also on species of Castilleja (Indian paint brush.)

Melampsorella elatina (Fir-chickweed rust). (Fig.7).

This fungus causes conspicuous witches' brooms on grand and alpine fir. In the early spring the brooms are conspicuously yellow due to the spore masses produced by the needles. After the production of the spores the needles fall leaving the brooms bare, and for this reason are easily distinguished from brooms caused by mistletoes. The fungus frequently dwarfs and deforms the terminal shoot of young trees, also causing cankers and swellings on the main trunk of more mature growth, making an entrance for cull fungi. The fungus has its alternate stage on the common chickweed and related plants.

Melampsorella coloradense (Spruce-chickweed rust).

This fungus is similar to the above named species, producing brooms on spruce and having its alternate stage on the same group of plants.

Fungi attacking the Fruit.

Melampsoropsis pyrolae (Spruce cone rust.)

Causes a disease of the sporophylls, shriveling the cones and reducing the quantity and quality of seed. Alternate stage on Pyrola species.

Fig. 7. Melampsorella elatina.

Fir - chickweed rust,
Forming witches broom on
Abies grandis.

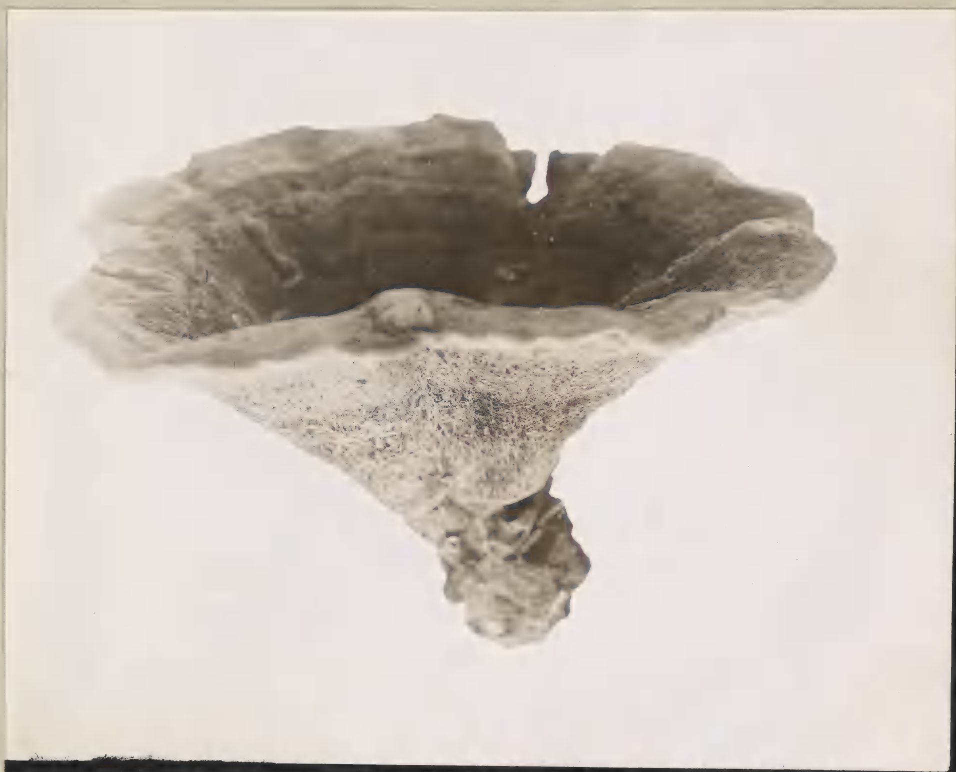

Fig. 8. Polyporus Schweinitzii.

(Velvet top fungus)

Growing out from roots of Western White Pine.

Fungi Attacking the Roots.

Polyporus Schweinitzii (Velvet top fungus.) (fig.8.)

Sporophores annual. with stipe, dark brown, velvety or covered with stiff hairs; flesh brown, soft and spongy when fresh, brittle when dry; the stipe is usually short and thick, and in most cases excentrically attached, sometimes wanting when growing from trunks. Pores large when young, becoming longer, irregular and lacerate when old.

From the standpoint of rapid loss in vitality Polyporus Schweinitzii Fr. is probably as much to be feared as an enemy of our valuable species as any other fungus. Often working in cooperation with Fomes pini, a rapid destruction of all merchantable parts of the trees soon results. Polyporus Schweinitzii enters its host either through wounds at the base of the tree or directly attacks the roots not previously injured. After traversing the more superficial root system, the mycelium enters the heartwood of the trunk causing the well known "butt" or "red brown rot". Isolated infections are very rarely found; where one tree is infected its neighbors in most cases will likewise become diseased. The root systems of trees in a crowded stand are usually in contact, or, as in some cases, in physiological connection. Spreading in the heartwood of infected roots the fungus is enabled to encompass many trees in a comparatively short time. The rot seldom extends upward in the trunk more than the first log length, five to eight feet is the usual average. Since the fungus travels through the soil and does not always fruit,

its presence in the stand is hard to detect and is still more difficult to combat. In logging operations great care should be taken to extend the cutting areas around clumps of trees infected with this fungus. If the pathological survey of a proposed sale shows that clumps of infected trees stand on the boundary of the sales area they should be included in the sale. If the brush is piled and burned, as many piles as is convenient should be made on stumps of infected trees in order to burn the roots as far into the earth as possible. Fire injury to parts of trees above ground may not be a means of entrance by this fungus, hence it is not likely to become prevalent in those trees left standing on an area where fire has been employed. Steps should be taken, however, to eradicate all the infected trees on the sales area.

Refer To Feb 1950 - (Vol XXIV #1) issue of Northwest Science - By E.E. Hubert - 10 pages about "Root rots in WP Type."
[illegible] 12/18/51

<u>Armillaria melles</u> (Honey mushroom.)

Sporophore annual, mushroom type, honey colored but varying in color to brown; upper surface marked with tufts of brownish hairs, especially at center, and with scales; margin of pileus often striate, stem stout, tall, whitish, yellowish or brownish, smooth or scaly, with a conspicuous ring; gills whitish or yellowish. Produces an abundant mycelium forming fan-shaped sheets under the bark, later breaking up to form shiny dark strands or rhizomorphs. The mycelium penetrates the cambium layer, attacking the living cells and girdles the tree.

The universal occurrence of this fungus in the forests of the Northwest is of serious consequence and must be taken

into account in the silvical projects for many regions. The fungus is easily recognized by its habit of growing in clumps about the base of the infected tree, its conspicuous honey colored pilei when young, turning yellowish-brown when old. By removing the bark from the base of infected trees, the white palmate spreading mycelium which is so typical of this fungus, is generally exposed and is an infallible means of determining the fungus. The fungus is further characterized by its habit of producing rhizomorphs, cylindrical or ribbon-like strands of mycelium which ramify into all directions between the bark and wood of living trees. These rhizomorphs extend into the earth, spread to adjacent trees, and is a most effective agent in extending the disease. After the destruction of the cambium the mycelium begins to attack the wood, particularly the parenchyma of the resin canals. The destruction of these cells produces an abnormal resin flow, both within and without the bark, cementing the soil about the base of the tree in a most characteristic manner. Within a comparatively short time after the fungus girdles the tree and the flow of resin appears, or even before, the tree dies.

The fungus attacks all age classes, but is particularly common on young growth. The rapidity with which young four to fifteen-year-old trees succumb to the attack of this fungus after they have made an excellent growth for the year, is common observation in the early autumn in many old cuttings and in the forest fire areas. The infected trees yellow-up and die quickly, by which this type of injury may be readily distinguished from the long period of sickly growth following

an attack of insects or from the effects of drought.

The activities of Armillaria mellea does not end with the death of the host, but continues to fruit about the base of the tree or stump as long as there is sound wood remaining. The rhizomorphs have the ability to remain viable under the bark and for this reason the fungus will be extremely hard to eradicate and explains its presence in areas swept by fire. The fungus, however, may be killed in the forest soil away from the base of stumps or trees by severe ground fires, since the rhizomorphs seldom develop more than two to six inches under the soil. These strands may follow roots of trees to a much greater depth, and a fire may not have much effect on them unless the stump is entirely consumed.

Fomes annosus (Root Fomes.) (fig.9.)

The sporophore is woody, usually thin and irregular in outline, with a smooth, brown crust, and is perennial; the context is white or pale yellowish; pores small and round, conspicuously stratified, white to yellowish.

This is a root fungus causing considerably more damage in our western forests than was formerly supposed. The fungus is difficult to detect, owing to the fact that the sporophores are usually produced deep in the root spur and are frequently covered with the forest debris. The mycelium produces a red rot, later delignifying the summer wood, which usually in badly infected specimens includes the entire heartwood of the base of the tree, often extending upward for several feet. The fungus spreads either by direct contact of the roots of neigh-

Fig. 9. Fomes annosus.

(Root fomes)

Sporophores from roots of

Western White Pine.

boring trees or by means of spores. As in the case of Armillaria mellea a flow of resin is produced from the infected parts, but the subcortical mycelium of Fomes annosus may be readily distinguished from that of the former by its greater delicacy and shiny whiteness. Young, as well as old, trees are attacked. The fungus is found in 30-80 year old stands and occasionally on younger trees. Fomes annosus has been found to be more abundant and works greater injury wherever the trees occur in pure stands, especially when the stand is overstocked. This is directly due to the close relation of the root system which enables the fungus to spread from one tree to another. The fungus does not occur so abundantly in mixed stands of white pine, larch, cedar, with a sprinkling of birch, alder, etc., neither in stands on the more mineral soils. White pine stands first in order of hosts infected, hence the presence of other conifers, also hard woods which are likewise attacked, prevents the close association of the root systems of trees of the same species.

Poria Weirii (Brown cedar Poria). (Fig. 10.)

Sporophores entirely resupinate, perennial, stratified, pores and context brown throughout. Grows in root crotches of standing trees, or spreads along the underside of fallen trunks. Always inconspicuous.

The brown cedar Poria is chiefly responsible for the prevailing butt rot in western red cedar and is the chief enemy of this valuable species. Trees of a comparatively young age class are affected. In dense pure stands this fungus is particularly destructive. Its mycelium sometimes grows through

Fig. 10. Poria Weirii (Brown cedar poria)

causes butt rot in Western red cedar

Thuja plicata.

the forest mold, matting it into huge layers, and by this means increases the original area of infection. The fungus causes a yellowish-white laminated rot which may extend for a considerable distance in the heartwood, varying with the age of the tree.

Fungi Attacking the Needles.

Ascomycetes.

The most important needle fungus of the western white pine is *Lophodermium pinastri* (needle cast fungus) and is the cause of the extensive browning of the needles of this tree in many regions of northern Idaho. The fungus plays a prominent part in hastening the suppression of trees in mature forests. Sometimes it takes on epidemic tendencies and attacks the needles of trees of all ages. White pine stands in moderately deep ravines uniformly turn brown and appear from a distance as if scorched by fire. The disease has also very recently appeared in the forest nursery. It is a very common cause of death of young seedlings in the forest.

Among other important needle parasites may be mentioned *Lophodermium nervisequium* (needle nerve fungus) causing defoliation of grand and alpine fir; *Hypodermella laricis* (larch leaf cast), causes a serious defoliation of western larch in dense stands; *Keithia thujina* (cedar Keithia) is a serious defoliator of western red cedar, sometimes epidemic on young seedlings in the forest; *Hypoderma deformans* (pine broom fungus) causes large conspicuous brooms on yellow pine; *Phacidium infestans* (fir leaf cast fungus) is sometimes destructive to the

Fig. 11. Witches brooms.

on

Larix occidentalis
caused by
Rasoumofskya laricis.

leaves of firs; Herpotrichia nigra (Black cobweb fungus), and Neopeckia coulteria (pine cobweb fungus), are common in alpine regions, the former usually on hemlock and fir, the latter on pine, but are relatively unimportant except in the case of nurseries situated at high elevations.

Rusts:

Melampsora albertensis (Douglas fir-poplar rust), M. medusae (larch-poplar rust), Coleosporium solidaginis (pine-golden rod rust), are common forest tree rusts in our region, but rather unimportant in the forest, but could be serious in the nursery.

There are many other twig and needle blights of coniferous trees, but they are more or less transitory and should not be greatly feared. Extreme weather conditions are often responsible for the browning up of the needles of conifers. Such conditions may result in serious complications, with semi-parasitic fungi or insects, but injury of this nature usually disappears on the return of normal weather.

3. Diseases caused by Phanerogamic Plants, Mistletoes.

Mistletoes injury to coniferous trees in northwestern forests is sometimes so extensive as to assume in some regions the nature of a serious forest problem. The most common mistletoes and the hosts on which they are found are Razoumofskya laricis, (the larch mistletoe) (fig.11), R. campylopoda, (Pacific coast yellow pine mistletoe) (fig.12), R. americana, (lodgepole pine mistletoe), R. douglasii, (Douglas fir mistletoe) (fig. 13), R. cyanocarpa, (small white pine mistletoe), also on limber and white bark pine, R.

Fig. 12. Female plant of
Razoumofskya compylopoda,
the yellow pine mistletoe.

Fig. 13. Witches brooms on

Pseudotsuga taxifolia

Razoumofskya douglasii.

tsugensis, (hemlock mistletoe), and R. occidentalis abietina, on firs (large leafless mistletoe of fir.)

The general nature of the injury by these mistletoes is expressed in a gradual reduction of the leaf surface of the host, which causes a great reduction of growth in height and diameter.

New infections take place only through the agency of a germinating seed, which reaches the point of infection through the natural expelling force of the seed capsule, which may be made more effective in point of distance traveled by the aid of strong winds, by falling from branches above after they have been loosened from their original resting place by rains, and by animal life.

Trees of all age classes are liable to infection provided the mistletoe seeds fall on parts of the host not yet protected by the mature cortex. The parasite may spread from the original point of infection into older cortical tissues, which are not liable to infection from without. The spread of the cortical strome in the reverse direction from the line of growth of the branch may continue until the outer cortex becomes too thick for the aerial shoots to penetrate it. After this, the cortical roots become suppressed and eventually die, or they may become wholly parasitic.

Excessive mistletoe infection of the lower branches of a tree may cause the upper portion of the crown to die, giving rise to the phenomenon commonly called staghead or spiketop. Severe infection throughout the entire crown often results in

the death of the tree. Young seedlings from 3 to 6 years old are often killed within a comparatively short time after infection.

Infection on the branches in practically all cases causes the formation of large brooms, which seriously interfere with the life function of the tree. The same is true in the case of infection on the trunk, whereby burls are formed.

The weakening effect of the formation of burls and brooms by mistletoe on forest trees is often responsible for serious depredations by fungi and forest-tree insects.

In point of quality and quantity the seed-producing capacity of the trees suppressed by mistletoe is far below that of normal uninfected trees.

Mistletoe can be controlled. It is suggested that a beginning may be made in its eradication or in the reduction of the ravages caused by these parasites by working along the lines indicated in U.S.D.A. Bulletin No. 360, and in the Journal of Agricultural Research, Vol. 12, p. 718, 1918.

It is seen from the foregoing that the forests of northwestern Montana and northern Idaho are heavily affected by wood-rotting fungi. This condition is due to the humid climate, dense stands, great areas of virgin timber which have never been under management, and the presence of hemlock and white fir and white pine which seem particularly predisposed to disease.

The sporophores of wood-destroying fungi produce spores in enormous quantities. Certain fungi which produce spores during the early part of the season usually renew their spore

production during the fall and rainy season, and some of the most destructive fungi show extreme hardiness in that they are frequently able to grow and sporulate in mild weather in winter.

Spores are carried to greater distance within the open stands than in denser timber, but since the forests are drier because of greater atmospheric circulation, the effect is somewhat counterbalanced. Similarly, though spores from trees in exposed situations are carried much farther than those from close forests, the former are less affected by virtue of the drier sites. Below is summarized the most important tree diseases occurring in this region, which when used in conjunction with the brief descriptions previously given, may be used for purposes of identification.

Host Index for the Principal Fungi and Mistletoes,

of Northwestern Conifers,

or District One.

Western White Pine
Fomes pini (Ring scale fungus)
Polyporus Schweinitzii (Velvet-top fungus)
Fomes annosus (Root Fomes)
Armillaria mellea (Honey mushroom)
Lophodermium pinastri (Needle cast fungus)

Western Yellow Pine
Fomes pini
Hypoderma deformans (Pine broom fungus)
Polyporus Schweinitzii
Fomes laricis (Chalky quinine fungus)
Cronartium Harknessii (Pine gall-Castilleja rust)
Cronartium Comandrae (Pine-Commandra rust)
Cronartium stalactiforme (Pine-blister-Castilleja rust)
Razoumofskya campylopoda (Pacific Coast Yellow Pine mistletoe).

Lodgepole Pine
Coleosporium solidaginis (Western pine-golden rod rust)
Fomes Pini
Polyporus Schweinitzii
Cronartium Harknessii
Cronartium Comandrae
Cronartium stalactiforme
Neopeckia Coulteri (Pine cobweb fungus)
Razoumofskya americana (Lodgepole pine mistletoe)

Western Larch
Fomes pini
Fomes laricis
Fomes pinicola (Red belt Fomes)
Hypodermella Laricis (Larch leaf cast)
Polyporus Schweinitzii
Melampsora medusae (Larch-poplar rust)
Razoumofskya Laricis (Larch mistletoe)

Douglas fir
Polyporus Schweinitzii
Fomes pini
Polyporus sulphureus (Sulphur fungus)
Razoumofskya douglasii (Douglas fir mistletoe)
Melampsora albertensis (Douglas fir-poplar rust.

Engelmann Spruce
    Fomes pini
    Fomes annosus
    Polyporus Schweinitzii
    Melampsorella elatina (Fir-chickweed)
    Melampsorella coloradensa (Spruce-chickweed rust)
    Melampsorella pyrolae (Spruce cone rust.)

Western Red Cedar
    Poria Weirii (Brown cedar Poria)
    Polyporus Schweinitzii
    Fomes pini
    Keithia thujina (Cedar Keithia)

Western Hemlock, Mountain Hemlock
    Echinodontium tinctorium (Indian paint fungus)
    Fomes annosus
    Fomes pinicola
    Herpotrichia nigra (Black cobweb fungus)
    Pholiota adiposa (Scaly or fatty Pholiota)
    Razoumofskya tsugensis (Hemlock mistletoe)

Grand and Alpine Fir
    Echinodontium tinctorium (Indian paint fungus)
    Fomes annosus
    Fomes pinicola
    Lophodermium nervisequium (Needle nerve fungus)
    Phacicium infestans (Fir leaf cast fungus)
    Pholiota adiposa
    Razoumofskya occidentalis abietina

White bark and Limber pine
    Most of the common wood destroyers and
    Razoumofskya cyanocarpa (large white pine mistletoe).

Practical Considerations on the Control of Disease in the Forest.

The saving of money in the operation of National Forests can be compared to the various methods of economy applied to any business. There are many ways in which this economy can be practical on National Forests in respect to the part which forest pathology plays in their administration. Among the more important points aimed at better economics and direct

saving the following may be mentioned, as proposed and demonstrated by the Forest Pathologist in this District: (1) Prevention of direct loss by proper protection from disease of forest nurseries, plantations, and, hence, to the forest; (2) Prevention of spread of diseases by proper timber sale regulation; (3) Prevention of financial loss in operations by more nearly accurate timber surveys and later stumpage estimates of proposed sale areas; (4) Prevention of loss in stands due to rot by timely pathological surveys and the application of proper cutting ages to stands of timber which deteriorate in value after a certain period is passed due to increasing amount of rot in the stand; (5) Prevention of loss by windfall of seed trees and seed tree groups through rotting of roots and basal parts of the tree; (6) Direct saving in accurate judgment in scaling infected logs on sale areas; (7) Direct saving in close utilization of forest materials on sale areas, especially culled material caused by rot, and the possible utilization as by-products of all fungous infected material left over.

(1) The prevention of direct loss and subsequent financial loss by employing proper protective measures against diseases in forest nursery plantations, thus retarding the progress of disease in native stands of timber, is a first prerequisite. Prevention of future losses in seedlings, transplants, and merchantable timber is just as important, if not more so, than the salvaging of material partially lost by the attack of forest tree diseases. It is the aim of the forest planter to restock a certain denuded or burned-over area with suitable seedlings

at a minimum cost. This cost can be appreciably affected by the initial cost per thousand of raising these seedlings from the time of sowing to the time of transplanting in the plantation areas. The losses due to fungus attacks have considerable effect upon increasing the cost of these seedlings. Often entire beds of first-year seedlings are destroyed by fungous attack, and the entire cost of seed collection, storage, seed bed preparation, sowing, etc., is lost at once. Proper methods of prevention could save this loss or, at least, reduce it to a minimum. The collection of seeds having a high percentage of germination and from trees free from disease, improving sites for seed beds, removal of sources of infection in the vicinity of the nursery, a strict policy that all seedlings brought to the nursery from other sections of the country be free from disease, supplying the physiological requirements of the seedlings in the seed beds, and the direct application of fungicides to inhibit damping-off fungi, are some of the control measures to consider in growing seedlings.

(2) In the native forest the problem of preventing economic loss from disease becomes more difficult. Our virgin forests are very irregular in point of age class, density and mixture of species, and disease has run rife from the beginning unchecked. To make a beginning, data on loss through decay and other causes must be assembled. For example, the estimated loss in western white pine in this region due to rot by fungi equals $7,201,250. This computation is based on actual data taken on nine sale areas. The deterioration of stands of

western hemlock and grand fir in the Northwest represents an enormous loss from an economic standpoint. Many stands are found infected and in which individual trees run from 10 to 80 per cent in rot volume. Such stands usually represent a total loss, since logging such areas would be highly uneconomical. If logged before the rot percent became too high, it might have paid in conjunction with the felling of other species in the stand; but only a pathological survey at the proper time could have aided in establishing this point. This shows the necessity of determining the factors that will inhibit loss. Determine what species are inferior in point of susceptibility to disease, and by their gradual removal or discouragement in the general plan begin to bring about a reduction of the agents of infection. The technical application of the knowledge thus gained as regards these, as well as other more desirable species, will make it possible to balance loss data against increment and will lead to a proper appreciation of the relation of disease to silviculture.

The prevention of the spread of forest tree diseases by the enforcement of proper timber sale regulations is an important factor toward economic saving and should be at once put into effect after the importance of the role of forest tree diseases in forest management is realized. Prevention of epidemics of forest tree diseases which threaten to destroy large areas of reproduction can safely be classed as definite savings in so many dollars and cents. Future valuation formulas are applied in cases where trespass by fire has wiped out large areas of valuable seedlings and young growth. There is no reason why

such a formula could not be applied to areas threatened by destruction through fungous diseases or by mistletoe. If preventive mehtods shall have been successful in saving the crop, then the loss based on future valuation prevented can truly be called a saving. Sale regulations by enforcing the destruction of all infected standing and down material can insure a healthy crop of reproduction and can materially reduce the spread of disease.

(3) The prevention of financial loss in logging operations by more nearly accurate estimates of the sound contents of the stand is one of the factors considered as a direct saving in dollars and cents. This not only shows the necessity of giving proper consideration to the determination of cull due to rot in any given stand, but results in the accumulation of cull data of value in establishing cutting rotations.

(4) Timely pathological surveys and a resultant application of the proper cutting age to a stand which, due to the increasing amount of rot, is liable to deteriorate in value, are important in an effort to learn the status of health of a forest. Such work is also important from a dollar and cents basis. This phase of work has only been recently proposed by the Forest Pathologist and is the first work of the kind proposed in this country. If the cutting age of a stand can be determined beforehand so as to eliminate so far as possible the chances of cutting the stand when the rot has progressed so far as to make the logging operation a loss, then the resulting saving will be worth the effort and the cost of a pathological survey of the

area.

Pathological surveys of the stand as a whole and studies on individual trees of an area representative of particular types and conditions have led to the following results applicable to management and the control of disease: It has been possible to take definite steps in the application of forest pathology to forest management in that proper marking rules have been formulated. These rules offer means whereby forest sanitation may be secured over such areas where the value of the species of the tree cut and the economic factors allow of more intensive methods in the control of forest tree diseases. Since the aim of forestry is to produce future crops, the efforts of forest pathology work are linked with this, and the aim is to produce crops of maximum soundness and, therefore, of least loss. These rules have been applied to the principal forest types of District One and have been made conformable to the silvicultural practice as at present applied to these types.

In the control of disease special attention must be given to the removal of infected trees below and above the specified diameter limits, an important phase brought out by the surveys and should not long be overlooked. Control measures are intimately associated with survey studies which have for their aim the establishment of an average age of earliest infection, which when based on the assumption that any rotation decided upon must be considered as approximate and that the cutting plan must provide for a reasonable leeway in cutting timber either before or after it has reached the rotation age, becomes highly important. In the case of western white pine, for all

principal rots found an age of earliest infection of 50 years was determined for the tree in general. For western hemlock in the Priest River region attacked by Echinodontium tinctorium, the average age of first infection for the river bottom type is approximately 44 years, and for the slope type 57 years.

The next step is to establish a pathological felling age, a limiting factor in rotation. This will be found to vary with the species of tree diseases concerned and the site (See U.S.D.A.Bulletin No. 799).

In considering the relative practical importance of these ages the correct assumption, it would seem, would be to fix the rotation age sufficiently near the average age of infection so that there would be no question about actually cutting the timber, at least by the time the second joint in the life history of the stand was reached and which has been designated as the age at which the decay becomes common and causes a serious economic loss.

The fact that these surveys bring out the fact that the amount of decay bears a certain relation to the age of a stand makes it possible to prepare cull tables giving the rot percentage for a range of age classes for each tree species. These tables are of value to the estimator in determining the rot percentage for each type of forest and replace the old empirical method of judging the amount and extent of defect. Tables have been prepared for western white pine and western hemlock, as follows:

Table of Rot Per Cents for Western Hemlock

Western White Pine.

A.C. = Age class
T.R. = Trunk rot
B.R. = Butt rot.

Bottom Site

A.C. Years	Western Hemlock T. R.	Western White Pine B. R. & T. R.
41-60	0 -- 6.0	0 - 0
61-80	6.5 --12.0	0 - .16
81-100	12.5 --19.0	.17 - .72
101-120	19.5 --26.0	.73 -1.7
121-160	26.5 --33.0	1.8 - 3.1
161-200	33.5 --40.0	3.2 -15.7
201-	40.5 --60.0	15.8 -18.3

Slope Site

41-60	0. -- 1.0	0. - 0.
61-80	1.1-- 2.5	0. - .06
81-100	2.6-- 3.5	.07- .37
101-120	3.6-- 15.5	.38- .45
121-160	15.6-- 24.5	.46- 2.3
161-200	24.6-- 33.0	2.3 - 2.4
201-	33.1-- 37.0	2.5 -14.7

Hemlock figures from studies made near Priest River, Idaho, based on 201 trees.

White pine figures from studies made on the Coeur d'Alene National Forest, Idaho, based on 1,245 trees.

After a sale by the selective method it becomes important to determine the influence of thinning on the remaining trees. The studies so far made show the effects on sporophore development in that their activities are greatly curtailed thus lessening the chances of infecting the remaining or future stand. This is in addition to the value to be derived from such studies as regards forest management.

Lastly, it is recommended that the Forest Service should carry out, so far as is practicable, all phases of forest sanitation work. By this is meant the direct supervision by Forest officers of all stages in the administration of timber sales which have to do with freeing the area of infectious material threatening new growth and the remaining stand. This is better than to leave so much of the sanitation work in the hands of the operator.

(5) The prevention of loss by windfall of seed trees and seed tree groups through the rotting and weakening of roots by fungi is another important consideration in disease control, and is also important from a financial standpoint. Seed trees, whether left singly or in groups, are in many cases the sole source to be depended upon for the restocking of the cut-over areas. If, then, trees are not selected properly, and heart-rotted or butt-rotted trees are left on the area, the weakening of the roots coupled with the exposure due to the cutting operations will result in windfalls and the trees will be lost as well as the potential value in respect to restocking the area with new growth. This also applies so far as the actual value

of the trees is concerned, to trees marked to be reserved in selection cuttings. These trees should be free from root, butt and trunk rots. The opening up of the stands by selection cutting exposes the remaining trees to the force of the wind, and if trees are left whose roots or trunks are weakened by fungi, windfall will result in one case and wind breakage in the other.

The estimated loss due to fungi in causing windfall amounts to $23,642 in Forest Service, Districts One, Two, and Six. This comprises 3 per cent of the total loss. In western white pine left as seed trees on cut-over areas in the Coeur d'Alene National Forest approximately 50 per cent of these trees were a complete loss due to windfall caused by fungi. Loss due to windfall by fungous attack in seed trees or in trees marked to be reserved in selection cuttings can be prevented by a strict enforcement of a general recommendation aiming to select trees free from root, butt, and trunk rots. The demand for a large cut frequently prevents the adoption of many things known to be good forestry.

(6) In the scaling practice in effect upon National Forests there are many opportunities calling for an application of the knowledge of forest tree diseases and leads to better forest sanitation. A scaler who has been trained to recognize all the signs and indications which give him a better understanding of how the rot in the log extends will unquestionably come nearer determining the correct scale of that log than one who has not. Each rot in most cases caused by a distinct fungus has

its own peculiarities and behaves differently as to its spread in the tree. Also the same rot varies in its method of attack on the wood, in some cases acting as a typical butt rot, again as a heart rot. Sometimes it is patchy in habit, again it will be found to extend uniformly in the heartwood. These and many other points of practical value to scalers should be carefully studied and recorded so that the men who must be depended on for the correct scaling of the logs can be better equipped to handle these varying conditions. In this case actual saving can be practiced in the correct scaling of infested logs so that neither a waste is incurred by overlooking merchantable sound material or overestimating the cull nor a loss incurred by underestimating the cull and so allowing logs to be shipped to the mills and there found useless. In scaling hemlock and grand fir logs, it is particularly important that the scaler recognize the earlier stages of the rot caused in the heartwood by the Indian paint fungus. The early stages of decay in this instance is very difficult to detect and if the logs are allowed to go to the mill as sound material, upon cutting wet boards and during the drying process, it will be found that many of the boards fall into dry crumbly decay. The action of the fungus in the heart-wood does not become noticeably prominent until the boards dry. A knowledge of the characteristics of the rot applied through the scaler may in many instances save considerable money by preventing infected material from being sawed into boards and then found to be unmerchantable. There are as many more applications of this method of saving by way of correct scaling

as there are kinds of rots and species of trees. Each rot and each tree species present problems distinctly characteristic and the knowledge concerning them should be applied in a technical manner in order to get the highest returns on money invested in logging operations.

(7) One of the greatest opportunities for the immediate realization of a financial return from forest growth and a reduction of the activities of cull-producing fungi lies in the production of pulp. Modern life has found uses for wood pulp practically without end. Pulp as manufactured from various species of trees is of varying quality and is consequently employed for various purposes. In times past the best quality pulp was obtained from those trees with wood composed of long strong fibers, such as spruce and fir. The researches of the Forest Products Laboratory have demonstrated that the wood of many other species of trees, although not possessing the qualities of the wood of spruce, produces pulp of great value in the trades. Up to the year 1913 no investigator had pointed out the fact that there are millions of feet of standing living trees in the forests of the Northwest attacked by delignifying fungi which could possibly be made to yield large quantities of low grade pulp. The suggestion was made in 1913 by the District Forest Pathologist after some experimentation that the wood of trees infected with the cellulose producing fungi and which was not accepted in the trades even as common lumber would in all probability make a fair grade of pulp for some purposes. The suggestion of using such wood for pulp, in view of the requirements in the case, seems on the face of it altogether un-

tenable. A publication[*] by Weir shows the possibilities of using fungous infected trees for pulp.

The use of fungous infected materials for the above named purposes would result in a tremendous saving in two ways. First, there would be the immediate utilization of rapidly declining forest materials, the non-use of which would entail great cost in freeing the forest from infectious material. This would undoubtedly result in a saving in the cost of slash disposal, which at the present time is paid to the operator by a reduction of stumpage. It must be remembered, however, that the cost of bringing such material to the mill would be very great, unless the conditions were very favorable.

Conclusion:

The control of disease in living forest is possible only in but few cases after infection. Under the present state of forestry in the Northwest large and general measures of disease control are out of the question. Sanitary and hygienic measures as indicated in the foregoing pages commensurate with current economic conditions can only be followed.

Briefly, the successful application of these principles aiming to reduce rot and decay in future forests depends in the main upon a recognition of the following points:

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[*] Weir, J.R. Some Problems in Conservation with Reference to Forest Hygiene. The Timberman, Portland, Ore., Sept. 1913.

1. Recognition of the outward signs and symptoms of the various diseases of standing living trees.

2. Fairly accurate judgment of the extent of rot in each tree found to be attacked by fungi, rusts and mistletoe.

3. Knowledge of the age of first infection of various species of trees.

Special considerations aiming to control forest diseases through timber sale operations are included with the marking rules for the individual stands and types. In general, this means the inclusion of a rigid forest sanitation clause in all timber sale contracts involving the utilization or the destruction by fire of all infectious cull material, as well as all infected unmerchantable trees left standing.